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Chemical Abundance Variations in Globular Clusters: Recent Results from Mildly Metal-Poor M5

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Abstract. We present a chemical composition analysis of 36 giant stars in mildly metal-poor globular cluster M5. In comparing the M5 results to those obtained in M4, a cluster previously considered to be a "twin" in age, metallicity and chemical composition, we find large star-to-star variations in the abundances of elements sensitive to proton-capture nucleosynthesis, similar [Fe/H] values, but factor of two differences in some α-capture, odd-Z and slow neutron-capture process elements. Among stars in globular clusters, apparently there are no definitive "single" values of [el/Fe] at a given [Fe/H] for many important elements.

1. Introduction

Large star-to-star abundance variations in C, N, O, Na, Mg and Al exist among bright giant stars in metal-poor globular clusters. Star-to-star abundance variations have been found in all metal-poor globular clusters in which the variations have been sought. In clusters with sufficiently large sample sizes, N is typically anti-correlated with O and C, Na is anti-correlated with O, and Al is

anti-correlated with Mg. The reader is referred to §1 of Ivans et al. (2001) for references to recent relevant reviews.

The abundance anti-correlations found among cluster stars likely result from proton-capture nucleosynthesis (where C and N are converted into N, Ne into Na, and Mg into Al). What is less clear is whether the synthesis takes place in the giants we presently observe (evolutionary scenario) or in a prior generation of more massive evolved stars that polluted the gas from which the present generation of stars was formed (primordial scenario). One expectation of the evolutionary scenario is that the distribution of these abundances should change with advancing evolutionary state. Thus as evolution proceeds, one might expect to find relatively more stars with low O and Mg and fewer with high O and Mg, and correspondingly more with high Na and Al and fewer with low Na and Al.

Given the importance of decoupling the evolutionary effects from primordial enrichments, we performed an abundance study of a sample of 36 giant stars in the mildly metal-poor globular cluster M5, to compare against the Ivans et al. (1999) large-sample study of the similar metallicity cluster M4. Details of the observations and analysis techniques are to be found in Ivans et al. (2001).

2. Abundance Results

Our M5 stars display the "classic" anti-correlations and correlations of O, Na and Al, the elements that are sensitive to proton-capture nucleosynthesis, as previously observed in brighter M5 stars as well as in other clusters observed by the Lick-Texas group (see Figure 1). These abundance patterns also correlate with the CN strengths. When the RGB + tip stars are binned into two evolutionary groups by log g, the groups possess statistically significant different means of distribution in [O/Fe]. On average, stars with lower log g values have higher O and lower Na abundances than stars with higher log g values.

Between clusters, we find that the variations of O and Na are correlated but the degree of variation appears to differ. The O vs Na anti-correlation in M5 resembles that found in the more metal-poor clusters M3, M10, M13 and NGC7006 ([Fe/H] ~ -1.5 to -1.6). M4's behaviour seems to be more like that of M71, a disk cluster of higher metallicity ([Fe/H] ~ -0.7). The range of these abundance variations seems to correlate as well with other observables. For instance, for these 7 clusters, in addition to binning by the "first parameter" (metallicity), the clusters can be binned by their "second parameter" (as quantified by the horizontal branch ratio) as well as by their orbital inclination.

In M5, we find that the abundance ratios for Mg, Si, Ca, Sc, Ti, V, Ni, Ba and Eu show no significant abundance variations and that these ratios are comparable to those of halo field stars of similar metallicities. However, in comparing the abundances of M5 to M4, we find that Si, Al, Ba and La are overabundant in M4 with respect to what is seen in M5, confirming and expanding results from previous studies (Brown & Wallerstein 1992; Ivans et al. 1999). In Figure 2, we display boxplots of these four elemental abundances as well as Eu, an *r*-process element, for M5, M4 and halo field stars of comparable metallicities. The "box" in each case contains the middle 50% of the data and a horizontal line indicates the median value of a particular element. The vertical tails indicate the total range of abundances, excluding mild outliers which are denoted by open circles.

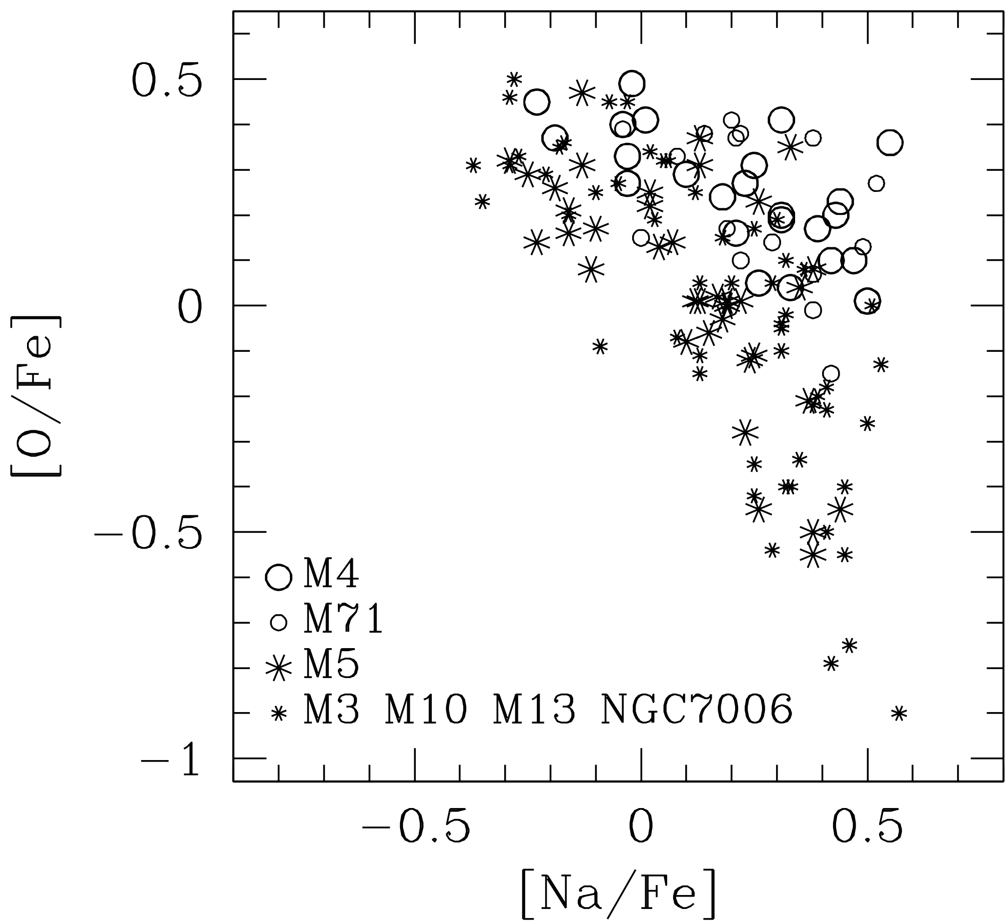

Figure 1. [Na/Fe] vs [O/Fe] for M5 and M4 in the context of globular clusters with similar metallicities previously studied by the Lick-Texas group (adapted from Fig. 16, Ivans et al. 2001).

3. Summary and Conclusions

In M5, we find correlations between CN, O, Na and Al that are both consistent with those seen in previous globular cluster studies and that follow the expected pattern of proton-capture nucleosynthesis. With clusters that bracket M4 and M5 in metallicity, we find that the abundance patterns can be divided into two groups: the O vs Na anti-correlation found in M5 resembles that found in slightly more metal-poor globular clusters M3, M10 and M13 whereas the M4 pattern resembles that of the more metal-rich disk cluster M71. The cluster similarities extend to the horizontal branch morphologies. We find good agreement between M5, M4 and field stars of comparable metallicity in the Fe-peak and α-element abundances, with the exception of a Si overabundance in M4. Ba and La are similarly overabundant in M4 with respect to M5 and the field, as is Al. Based on these large stellar samples for M5 and M5, we extend previous findings and

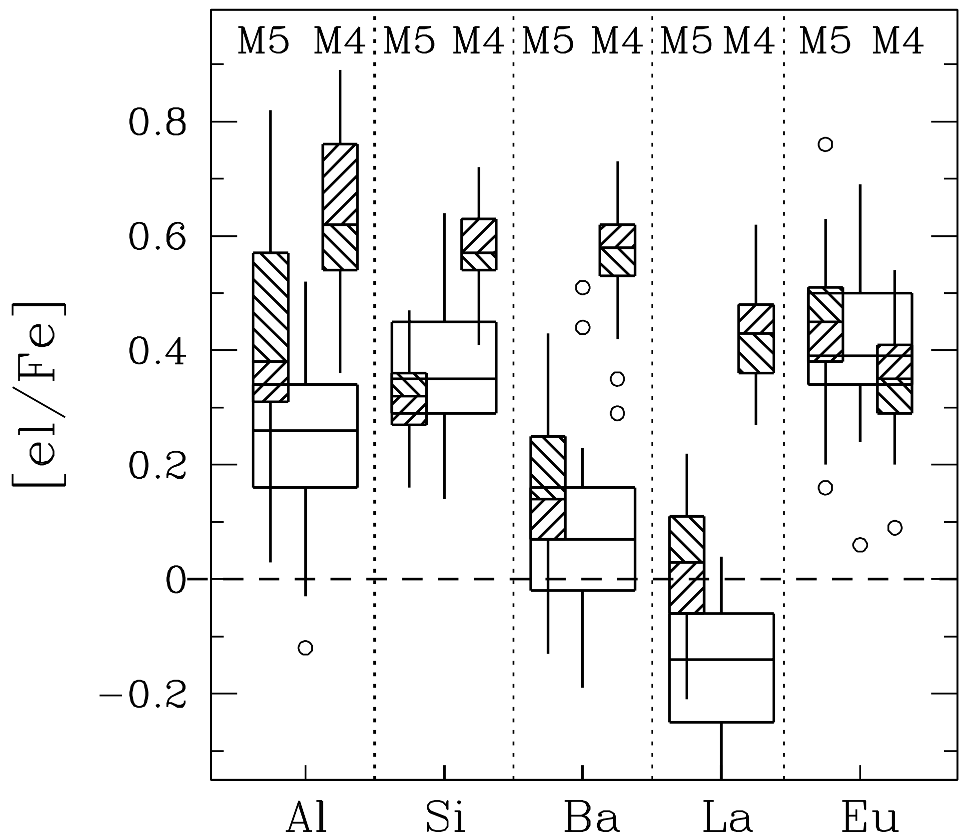

Figure 2. Boxplots of abundances of some odd-Z, α-capture, s- and r-process elements. In each panel, we show shaded boxplots for M5 (on the left) and M4 (on the right), both superimposed on an unshaded boxplot derived for the field halo stars of comparable metallicity.

conclude that there is no "single" value of [el/Fe] at a given [Fe/H] for at least some α-capture, odd-Z and s-process elements, in this case Si, Al, Ba and La.

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References

Brown & Wallerstein 1992, AJ, 104, 1818

Ivans, Sneden, Kraft, Suntzeff, Smith, Langer & Fulbright 1999, AJ, 118, 1273

Ivans, Kraft, Sneden, Smith, Rich & Shetrone 2001, AJ, 122, 1438

Sneden, Kraft, Prosser & Langer 1992, AJ, 104, 2121